PROCEEDINGS OF SCIENCE

Performance and Improvements of the ATLAS Level-1 Muon Trigger for Run 3

Yuichiro Hayashi[a,*]

[a] *on behalf of the ATLAS collaboration,*
International Center for Elementary Particle Physics (ICEPP), the University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033 Faculty of Science 10F, Japan

E-mail: yuichiro.hayashi@cern.ch

The LHC is starting the Run 3 operation aiming the luminosity leveled at a peak of 2.0×10^{34} cm^{-2}s^{-1} for 6-10 hours. In order to cope with the high event rate, the ATLAS Level-1 Muon trigger system has been upgraded. The Level-1 Muon trigger system identifies muons with high transverse momentum by combining data from fast muon trigger detectors, the Resistive-Plate Chamber (RPC) and the Thin-Gap Chamber (TGC). Since Run 3, the system introduced the improvement of the trigger logic using the new detectors "New-Small-Wheel (NSW)" and "RPC-BIS78", which are located in the inner station region for the endcap muon trigger. Information provided by the NSW and RPC-BIS78 can be used as part of the muon trigger logic to enhance the performance. In order to receive the extended data, new electronics have been developed, including the trigger processor board known as Sector Logic (SL). The SL board consists of a modern FPGA to make use of Multi-Gigabit transceiver technology, which will be used to receive data from the new detectors. The readout system for trigger data has also been designed for the extended trigger readout, with the data transfer implemented with TCP/IP instead of a dedicated ASIC, replacing the use of custom readout electronics with commodity servers and network switches to collect, format, and send the data. The trigger data readout is used for trigger logic commissioning, validation, performance measurement, and further improvements. These proceedings describe the upgrades of the Level-1 Muon trigger system. Particular emphasis is placed on the first results from the early phase of commissioning in 2022. The latest status of the system, the improvement, and expected performance are presented.

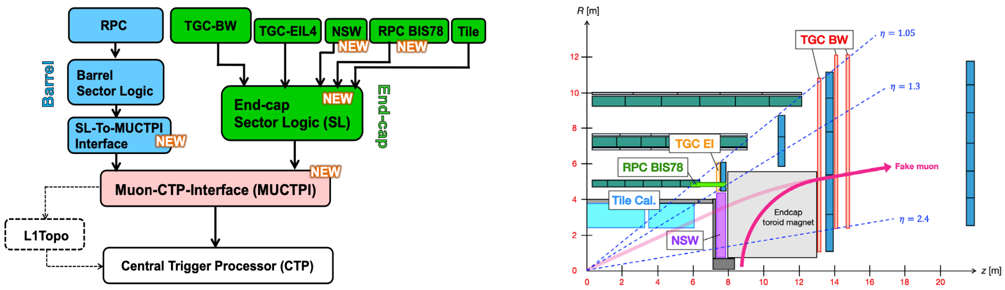
41st International Conference on High Energy physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

*Speaker

PoS(ICHEP2022)1004

1. Introduction

The muon trigger system of the ATLAS detector [1] in Run 3 consists of a hardware-based Level-1 Trigger (L1) and a software-based High-Level Trigger (HLT) [2]. The L1 trigger selection is based on the online muon objects reconstructed by the L1 Muon Trigger system (L1Muon). The overview of L1Muon is shown in Fig. 1 (a) and the layout of detectors which join L1Muon is shown in Fig. 1 (b).



(a) **(b)**

Figure 1: (a) Overview of L1Muon. In the figure, elements introduced in Run 3 are highlighted with "New". (b) Detector layout of the ATLAS Level-1 endcap muon trigger. In the figure, "fake" indicates the track of the charged particle which does not originated from Interaction Point (the origin in the figure). To suppress fake tracks, we introduced new elements in Fig. 1 (a) and use the coincidence of the muon chambers in the inner station and the Thin Gap Chamber Big Wheel (TGC BW) detector.

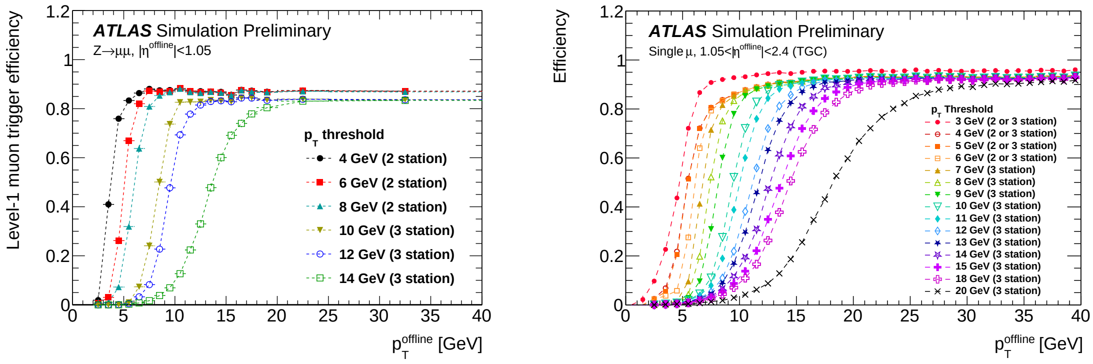
L1Muon consists of Endcap ($1.05 \leq |\eta| \leq 2.4$) and Barrel ($|\eta| \leq 1.05$) triggers. The muon reconstruction in L1Muon is performed by so-called Sector Logic (SL). The Endcap SL is based on the coincidence among layers of the Thin Gap Chamber (TGC) detectors and additional coincidence capabilities with the tile hadronic calorimeter and the muon chambers in the inner station. The Barrel SL is based on the coincidence of the Resistive Plate Chamber (RPC) layers. The Muon to Central Trigger Processor Interface (MUCTPI) receives the outputs from the Endcap and Barrel SL and sends them to Central Trigger Processor (CTP) and L1 Topological trigger (L1Topo).

L1Muon is upgraded for Run 3 (Phase-1 upgrade) [2]. Three new hardware components are introduced: the Endcap SL, SL-to-MUCTPI Interface in the Barrel, and MUCTPI. The new Endcap SL extends its I/O and FPGA resources available for trigger logic implementation. The extended resources allow us to have additional coincidence requirements with the track segments found in New Small Wheel (NSW) [3] detectors and RPC BIS78 detectors for improved background rejection in the trigger level (Fig. 1 (b)). The new MUCTPI has replaced from the old system consisting of 18 VME boards with a new single board having high-speed optical I/O and a large-scale FPGA. The SL-to-MUCTPI-Interface board is integrated for the Barrel to cope with the upgraded interface of MUCTPI input.

2. New features of the L1Muon Trigger in Run 3

In the upgraded L1Muon system, additional information can be provided by the Endcap and Barrel SL thanks to the extended bandwidth with high-speed links between SL Boards and MUCTPI.

The number of the p_{T} thresholds in the Endcap region is increased from 6 to 15. This allows us to tune trigger p_{T} threshold with a finer granularity, which extends the trigger rate control. Moreover the finer granularity improves the online event reconstruction in the L1Topo algorithm. The p_{T} thresholds in the Barrel regions have been coherently redefined. The performance studied by MC simulation is shown in Fig. 2.



(a) **(b)**

Figure 2: The figures show the efficiency of the Run 3 Level-1 single muon triggers as a function of the transverse momentum (p_{T}) of the reconstructed offline muon in the (a) Barrel and (b) Endcap region for various p_{T} thresholds, respectively. The efficiency is estimated using simulated $Z \to \mu\mu$ events (a) and simulated Single μ events (b) with new definitions of p_{T} thresholds for Run 3.

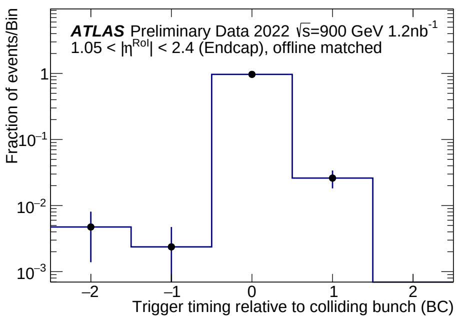
Furthermore, the SL output provides the following new features to provide a better selectivity. For Endcap, quality flags and charge information are added. Quality flags can indicate the condition of momentum resolution by either coincidence conditions or passage through a poor magnetic field region. Charge information is used by L1Topo to perform event selections. In the Barrel, a flag which specifies when more than two candidates are in a single RoI (Region of Interest) is added. It improves efficiency for close-by dimuon events.

3. Diagnostic tool development and timing calibration

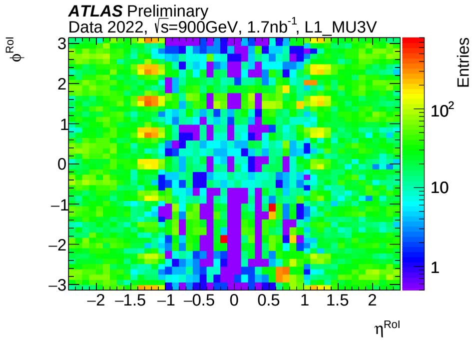
During the Phase-1 upgrade, tools to ensure stable operation from the beginning of Run 3 data taking have been developed. In particular, we exploited the test pulse functionality of the TGC system for the commissioning of the new endcap SL. It allows us to tune the timing parameters without muons from collisions. Also, with the dedicated readout test, we spotted malfunctioning electronics and optical links and cleaned them up.

4. System commissioning and early data analysis

We performed validation studies of L1Muon with actual data taken in cosmic runs and early 900 GeV collisions. In the Endcap, timing parameters, which are tuned in the test pulse runs, have been fully validated by the cosmic runs and LHC 900 GeV collisions (Fig. 3 (a)). In the Barrel, using the Run 3 initial data of $\sqrt{s}$ = 13 TeV, timing parameters have been fully validated. All



(a)



(b)

Figure 3: (a) The figure shows the trigger timing in only the Endcap, where cosmic muons are not major contributions, for a detailed study with offline muon matching required. The used events were recorded by other Level-1 items from muon in a colliding bunch so that L1Muon selection does not bias the timing distribution. (b) The distribution of RoI η and ϕ for L1MU3V. It shows the distribution of RoI η and ϕ for the Level-1 item L1_MU3V. The L1_MU3V is a L1 trigger item requiring thresholds of 3 GeV in the Endcap region and 4 GeV in the Barrel region.

Endcap and Barrel trigger systems participated in the commissioning runs. It is confirmed that all processors are functional with respect to the observed $\eta - \phi$ distribution in the commissioning runs (Fig. 3 (b)).

5. Summary

The Level-1 muon trigger has been upgraded with the new detectors and electronics for Run 3. The tools for diagnosing the system and monitoring have been developed. Validation of L1Muon with actual data taken in cosmic runs and early 900 GeV collisions is performed. The analysis using 900 GeV collisions yields the expected behavior of L1Muon in the Endcap. Timing in the Barrel has been fully validated using the Run 3 initial data of $\sqrt{s} = 13$ TeV.

References

[1] ATLAS Collaboration, JINST 3 (2008) S08003.

[2] ATLAS Collaboration, Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System, CERN-LHCC-2013-018, ATLAS-TDR-023 (2013). `https://cds.cern.ch/record/1602235`

[3] ATLAS Collaboration, New Small Wheel Technical Design Report, CERN-LHCC-2013-006, ATLAS-TDR-020 (2013) `https://cds.cern.ch/record/1552862`